U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 19.

IMPORTANT INSECTICIDES:

DIRECTIONS FOR THEIR PREPARATION AND USE.

[REVISED EDITION.]

BY

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., January 17, 1895.

SIR: I have the honor to transmit herewith a revised edition of Farmers' Bulletin No. 19, a condensed account of the more important insecticides for farm and garden use, prepared under my direction by Mr. C. L. Marlatt, first assistant entomologist. As stated in my letter of transmittal to the first edition, circular No. 1, new series, of this division, contained information of this character, but this document is out of print, and since it was published some advance has been made in the matter of insecticides which necessitates the publication of some additional matter and some change in the methods of preparation of old and standard mixtures. The constant call for information of this character will warrant the publication of this bulletin in large edition.

Respectfully,

L. O. HOWARD, *Entomologist.*

Hon. CHAS. W. DABNEY, Jr.,
Acting Secretary of Agriculture.

CONTENTS.

IMPORTANT INSECTICIDES: DIRECTIONS FOR THEIR PREPARATION AND USE.

Without going minutely into the field of remedies and preventives for insect depredators, it is proposed to give in this bulletin brief directions concerning a few of the insecticide agents having the widest range and attended with the greatest usefulness, economy, and ease of application. These are not covered by patent, and in general it is true that the patented articles are inferior, and many of the better of them are in fact merely more or less close imitations of the standard substances and compounds hereinafter described. Only such brief references to food and other habits of the insects covered will be included as are necessary to illustrate the principles underlying the use of the several insecticide agents recommended.

Relation of Food Habits to Remedies.

For the intelligent and practical employment of insecticides it is necessary to comprehend the nature and method of injury commonly due to insects. Omitting for the present purpose the many special cases of injury which necessitate peculiar methods of treatment, the great mass of the harm to growing plants from the attacks of insects falls under two principal heads based on distinct principles of food economy of insects, viz, whether they are biting (mandibulate) or sucking (haustellate), each group involving a special system of treatment.

INJURY FROM BITING INSECTS.

The biting or gnawing insects are those which actually masticate and swallow some portion of the solid substance of the plant, as the wood, bark, leaves, flowers or fruit. They include the majority of the injurious larvæ, many beetles, and the locusts.

For these insects direct poisons, such as the arsenicals, which may be safely applied to the leaves or other parts of the plant attacked, and which will be swallowed by the insect with its food, furnish the surest and simplest remedy, and should always be employed except where the parts treated are themselves to be shortly used for the food of other animals or of man.

INJURY FROM SUCKING INSECTS.

The sucking insects are those which injure plants by the gradual extraction of the juices, either from the bark, leaves, or fruit, and include the plant-bugs, plant-lice, scale insects, thrips, and plant-feeding mites. These insects possess, instead of biting jaws, sucking beaks or bristles, which are thrust down through the outer layers of the bark or leaves into the soft, succulent tissues beneath and used to extract the plant juices, with a resulting injury not so noticeable as in the first group, but not less serious.

For this class of insects the application of poisons, which penetrate little, if at all, into the plant cells, is of trifling value, and it is necessary to use substances which will act externally on the bodies of these insects, either as a caustic or to smother or stifle them by closing their breathing pores, or to fill the air about them with poisonous fumes. Of value also as repellants are various deterrent or obnoxious substances.

Wherever it is not desirable to use poisons for biting insects, some of the means just enumerated will often be available.

GROUPS SUBJECT TO SPECIAL TREATMENT.

The general grouping outlined above relates to the species which live and feed upon the exterior of plants for some portions or all of their lives, and includes the great majority of the injurious species. Certain insects, however, owing to peculiarities of habit, inaccessibility, or other causes, require special methods of treatment. Of these, two groups properly come within the scope of this bulletin: (1) Those working beneath the soil, or subterranean insects, such as the white grubs, root-maggots, root-lice, etc., and (2) insects affecting stored products, as various grain and flour pests.

Three other groups, which include species requiring very diverse methods of treatment, and therefore not coming within the limits of this bulletin, are (1) the internal feeders, such as wood, bark, and stem borers, leaf-miners, gall insects, and species living within fruits; (2) household pests, and (3) animal parasites.

The classification of insects outlined above, based on mode of nourishment and indicating groups amenable to similar remedial treatment, simply stated, is as follows:

I. External feeders:
  (*a*) Biting insects.
  (*b*) Sucking insects.
II. Internal feeders.
III. Subterranean insects.
IV. Insects affecting stored products.
V. Household pests.
VI. Animal parasites.

Insecticides for External Biting Insects (Food Poisons).

THE ARSENICALS: PARIS GREEN AND LONDON PURPLE.

The arsenical compounds have supplanted all other substances for the insects falling under this heading. Two compounds are in common use, viz, Paris green and London purple.[1] The use of powdered white arsenic is not recommended, on account of its greater liability to scald foliage and because it is very apt to be mistaken for harmless substances. Of the first two mentioned, Paris green is the stronger insecticide, acting quickly, and is less liable to burn foliage. London purple has the advantage of cheapness, and, being more finely powdered, is kept more easily suspended in water. The former can be had in 14-pound or larger cans at 20 cents per pound, and the latter at 10 cents per pound by the barrel.

HOW TO APPLY ARSENICALS.

There are three principal methods of applying arsenicals. The wet method, which consists in using these poisons in water in the form of spray, is the standard means, secures uniform results at least expense, and is the only practical method of protecting fruit and shade trees. The dry application of these poisons in the form of a powder, which is dusted over plants, is more popular as a means against the cotton worm in the South, where the rapidity of treatment possible by this method, and its cheapness, give it a value against this insect, in the practical treatment of which prompt and economical action are the essentials. This method is also feasible for any low-growing crop, such as the potato. The third method consists in the use of the arsenicals in the form of poisoned baits, and is particularly available for such insects as cutworms, wireworms, and local invasions of locusts.

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[1] A third arsenical which promises well, arsenate of lead, has lately been experimented with by the Gypsy Moth Commission. While not urging that this insecticide has advantages over Paris green, it is held that it has the merit of showing on the leaves, indicating at once which have been sprayed, remains much more easily suspended in water, and may be used in large proportions without danger to foliage. It has recently been extensively tested at the Department, and a strength as great as 1 pound to 2 gallons of water has been used on tender foliage of the peach and Osage orange without injury. Good results have attended its use also against the imported elm leaf-beetle. The insecticide results were not better, however, than with Paris green; but for such sensitive foliage as that of the peach, or where no risk of scalding may be taken, I am inclined to believe that it will prove useful.

This insecticide is prepared by combining, approximately, 3 parts of arsenate of soda with 7 parts of acetate of lead. These substances unite chemically and form a fine, white powder which remains easily in suspension. As now used by the Commission, 10 pounds of the arsenate of lead are used with 150 gallons of water, 2 quarts of glucose being added to cause the insecticide to adhere longer to the leaves. Professor Fernald's experience and our own would indicate that from one-fourth to one-half this strength will answer for most larvæ—the larvæ of the gypsy moth proving to be unusually resistant to the action of poisons. The arsenate of lead costs the commission 7 cents a pound wholesale, and glucose $16 a barrel.

The wet method.—Either Paris green or London purple may be used at the rate of 1 pound to 100 to 250 gallons of water, or 1 ounce to 6 to 15 gallons. The stronger mixtures are for such vigorous foliage as that of the potato, for the Colorado potato-beetle, and the greater dilutions for the more tender foliage of the peach or plum. An average of 1 pound to 150 gallons of water is a good strength for general purposes. The poison should be first made into a thin paste in a small quantity of water and powdered or quick lime added in amount equal to the poison used to take up the free arsenic and remove or lessen the danger of scalding. An excess of lime will do no injury. The poisons thus mixed should be strained into the spray tank or reservoir, care being taken that all the poison is pulverized and washed through the meshes of the strainer. The use of the lime is especially desirable in the case of the peach and plum, the foliage of which, particularly the former, is very tender and easily scalded. To the stronger foliage of the apple and most shade trees Paris green may be applied at the strength of 1 pound to 150 gallons of water without danger; with London purple it is always better to use the lime.

If it be desirable to apply a fungicide at the same time, as on the apple for the codling moth and the apple scab fungus, the Bordeaux mixture[1] may be used instead of water, adding the arsenical to it at the same rate per gallon as when water is used. The lime in this fungicide neutralizes any excess of free arsenic and makes it an excellent medium for the arsenical, removing, as it does, all liability of scalding the foliage and enabling an application of the arsenical, if necessary, eight or ten times as strong as it could be employed with water alone.

The arsenicals can not be safely used with most other fungicides, such as the sulphate of copper, eau celeste or iron chloride solution, the scalding effects of these in the mixture being greatly intensified.

The dry method.—The following description applies to the pole-and-bag duster commonly used against the cotton worm: A pole 5 to 8 feet

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[1]*Bordeaux mixture formula.*—Into a 50-gallon barrel pour 30 gallons of water, and suspend in it 6 pounds of bluestone in coarse sacking. Slack 4 pounds of fresh lime in another vessel, adding water slowly to obtain a creamy liquid, free from grit. When the bluestone is dissolved add the lime milk slowly with water enough to fill the barrel, stirring constantly.

With insufficient lime the mixture sometimes injures the foliage, and it should be tested with a solution obtained by dissolving an ounce of yellow prussiate of potash (potassium ferrocyanide) in one-half pint of water. If there be insufficient lime in the Bordeaux mixture the addition of a drop or two of this solution will cause a brownish-red color, and more lime should be added until no change takes place when the solution is dropped in. Use the Bordeaux mixture promptly, as it deteriorates on standing.

Stock solutions of both the bluestone and lime may be kept for any length of time. Make the stock bluestone by dissolving in water at the rate of 2 pounds to the gallon. The stock lime is slacked and kept as a thick paste. Cover both mixtures to prevent evaporation and keep the lime moist. For the 50-gallon formula add 3 gallons of the bluestone solution to 50 gallons of water, and introduce the stock lime slowly until there is no reaction with the testing solution.—B. T. G.

long and about 2 inches in diameter is taken, and a three-fourths inch hole bored through it within 6 inches of either end. Near each end is securely tacked a bag of "8-ounce osnaburg cloth," 1 foot wide and 18 inches to 2 feet long, so that the powdered poison may be introduced into the bags with a funnel through the holes at the ends of the pole. The bags are filled with undiluted Paris green, which is generally preferred to London purple on account of its quicker action, and the apparatus is carried, on horse or mule back, through the cotton fields, dusting two or four rows at once. The shaking induced by the motion of the animal going at a brisk walk or at a trot is sufficient to dust the plants thoroughly, or the pole may be jarred by hand. The application is preferably made in early morning or late evening when the dew is on, to cause the poison to adhere better to the foliage.

From 1 to 2 pounds are required to the acre, and from 10 to 20 acres are covered in a day. The occurrence of heavy rains may necessitate a second application, but frequently one will suffice. This simple apparatus, on account of its effectiveness and cheapness, is employed throughout the cotton belt to the general exclusion of more complicated and expensive machinery.

With the patented air-blast machines for the dry distribution of poisons, arsenicals are diluted with 10 parts of flour, lime, or ground gypsum, and from 60 to 75 acres may be covered in a day by using relays of men and teams. Greater uniformity is secured with these machines in distribution of the poisons, but their cost (from $30 to $60) prevents their general use.

The planter should have a good supply of poison on hand and apparatus for its application prepared in advance, since when the worm puts in an appearance its progress is very rapid, and a delay of a single day may result in material damage to the crop.

If small garden patches are dusted with poison by this or similar means from bags or with hand powder bellows, it is advisable always to dilute the poison with 10 parts of flour, or preferably lime, and for application to vegetables which may soon be used for food, as the cabbage, 1 ounce of the poison should be mixed with 6 pounds of flour or 10 of lime, and dusted merely enough to show evenly over the surface.

As poisoned bait.—It is not always advisable or effective to apply arsenicals directly to the plants, and this is particularly true in the case of the attacks of the grasshopper and of the various cutworms and wireworms. In such cases the use of poisoned bait has proven very satisfactory.

For locusts, take 1 part by weight of white arsenic, 1 of sugar, and 6 of bran, to which add water to make a wet mash. Place a teaspoonful of this at the base of each tree or vine, or apply a line of baits just ahead of the advancing army of grasshoppers, placing a tablespoonful of the mash every 6 or 8 feet, and following up with another line behind the first.

For baiting cutworms and wireworms, distribute poisoned green, succulent vegetation, such as freshly cut clover, in small bunches about in the infested fields. Dip the bait in a very strong arsenical solution, and protect from drying by covering with boards or stones. Renew the bait as often as it becomes dry, or every three to five days. The bran-arsenic bait will also answer for cutworms.

TIME TO SPRAY FOR BITING INSECTS.

For the codling moth, the apple and pear should receive the first application very soon after the blossoms fall, which is also the time for the second treatment of the scab fungus; the second spraying should be given one or two weeks later, just before the fruit turns down on the stem or when it is from one-fourth to one-half inch in diameter. The first spraying reaches the eggs laid by the moth in the flower end of the fruit shortly after the falling of the blossoms, and the second the later egg-laying by the more belated moths, when the first coating of poison will probably have been washed off by rains. The young larva, eating its way from without into the fruit, gets enough of the poison to destroy it. This treatment reaches at the same time a large number of leaf-feeding enemies of these fruit trees.

For the Curculio of the stone fruits, plum, cherry, peach, etc., two or three applications should be made; the first before the trees bloom or as soon as the foliage is well started, the second at the time of the exposure of the young fruit by the falling of the blossoms, and perhaps a third a week later, particularly if rains have intervened after the last treatment. The poison here acts to destroy the parent Curculio instead of the young larvæ, which, hatching from eggs placed beneath the skin of the fruit, are not affected by the poison on the outside. The adult Curculio, however, as soon as it comes from its hibernation feeds on the foliage before the trees bloom, and later on the young fruit also, and is destroyed by the arsenical before its eggs are deposited.

For leaf-feeding insects in general, such as the Colorado potato-beetle, blister beetles, elm leaf-beetle, maple worm, etc., the application should be made at the earliest indication of injury and repeated as often as necessary. Fruit-trees should never be sprayed when in bloom on account of the liability of poisoning honey bees or other insects useful as cross fertilizers.

CARE IN USE OF ARSENICALS.

It must be remembered that these arsenicals are very poisonous, and should be so labeled. If ordinary precautions are taken there is no danger to man or team attending their application, and the wetting of either, which can not always be avoided, is not at all dangerous, on account of the great dilution of the mixture, and no ill results whatever have resulted from this source.

The poison disappears from the plants almost completely within

twenty to twenty-five days, and even if the plants were consumed shortly after the application an impossible quantity would have to be eaten to get a poisonous dose. To illustrate, in the case of the apple, if the entire fruit were eaten, core and all, it would take several barrels at a single sitting to make a poisonous dose (Riley), and with the cabbage, dusted as recommended above, 28 heads would have to be eaten at one meal to reach this result (Gillette). It is preferable, however, to use other insecticides in the case of vegetables soon to be eaten, and thus avoid all appearance of danger.

INSECTICIDES FOR EXTERNAL SUCKING INSECTS (CONTACT POISONS).

The simple remedies for this class of insects, such as soap and lye washes, tobacco decoction, etc., are frequently of the greatest service, but need no special explanation. The whale oil is the most valuable of the soaps, and at the rate of 1 pound to 4 gallons of water, dissolved by heating, kills most soft-bodied insects, and at 1 to 2 pounds to the gallon is an effective winter wash for scale insects, even the very resistant San José scale succumbing to the latter strength. The insect powders (Pyrethrum or Buhach) are effective, but too expensive for any but limited or indoor use. The following are standard remedies for this group of insects: Kerosene emulsions, resin washes, hydrocyanic acid gas, and vapor of bisulphide of carbon.

THE KEROSENE WASHES.

The kerosene and soap emulsion formula.

Kerosene	gallons..	2
Whale-oil soap (or 1 quart soft soap)	pound..	½
Water	gallon..	1

The soap, first finely divided, is dissolved in the water by boiling and immediately added boiling hot, away from the fire, to the kerosene. The whole mixture is then agitated violently while hot by being pumped back upon itself with a force pump and direct-discharge nozzle throwing a strong stream, preferably one-eighth inch in diameter. After from three to five minutes' pumping the emulsion should be perfect, and the mixture will have increased from one-third to one-half in bulk and assumed the consistency of cream. Well made, the emulsion will keep indefinitely, and should be diluted only as wanted for use.

The use of whale-oil soap, especially if the emulsion is to be kept for any length of time, is strongly recommended, not only because the soap possesses considerable insecticide value itself, but because the emulsion made with it is more permanent, and does not lose its creamy consistency, and is always easily diluted, whereas with most of the other common soaps the mixture becomes cheesy after a few days and needs reheating to mix with water. Soft soap answers very well, and 1 quart of it may be taken in lieu of the hard soaps.

In limestone regions or where the water is very hard some of the soap will combine with the lime or magnesia in the water and more or less of the oil will be freed, especially when the emulsion is diluted. Before using, such water should be broken with lye, or rain water employed; but better than either, follow the milk emulsion formula, with which the character of the water, whether hard or soft, does not affect the result.

The kerosene and milk emulsion formula.

Kerosene	gallons.. 2
Milk (sour)	gallon.. 1

Heating is unnecessary in making the milk emulsion, which otherwise is churned, as in the former case. The change from a watery liquid to a thick buttery consistency, much thicker than with the soap, takes place very suddenly after three to five minutes' agitation. With sweet milk difficulty will frequently be experienced, and if the emulsion does not result in five minutes, the addition of a little vinegar will induce prompt action. It is better to prepare the milk emulsion from time to time for immediate use, unless it can be stored in quantity in air-tight jars, otherwise it will ferment and spoil after a week or two.

How to use the emulsions.—During the growing period of summer, for most plant-lice and other soft-bodied insects, dilute the emulsion with from 15 to 20 parts of water; for the red spider and other plant mites the same, with the addition of 1 ounce of powdered sulphur to the gallon; for scale insects, the larger plant bugs, larvæ, and beetles, dilute with from 7 to 9 parts water; apply with spray pump.

For winter applications to the trunks and larger limbs of trees, in the dormant and leafless condition, to destroy scale insects, stronger mixtures may be used even to the pure emulsion, which latter can not be sprayed successfully but may be applied with brush or sponge. Diluted with one or more parts of water it may be applied in spray without difficulty. The use of the pure emulsion is heroic treatment and only advisable in cases of excessive infestation, and in general it is much better and safer to defer the treatment until the young scales hatch in the spring, when the nine-times diluted wash may be used with more certain results and without danger to plants. The winter treatment should be followed by a use of the spring wash to destroy any young which may come from female scales escaping the stronger mixture.

Pure kerosene.—The pure oil may be applied as a winter wash to the older parts of plants either in a spray or with a sponge, using the least possible quantity. Its use is not advised save in exceptionally bad cases of infestation and during the dormant period, and should never be attempted after the first sign of spring growth appears.

In many cases plant-bugs and beetles may be jarred into cloths saturated with kerosene or into pans with water and oil and destroyed, where it would be unsafe or inadvisable to spray the plants themselves.

As a remedy against the mosquito, kerosene has proven very effective

(Howard). It is employed to destroy the larvæ of the mosquitoes in their favorite breeding places in small pools, still ponds, or stagnant water, and where such bodies of water are not sources of drinking supply or of value for their fish, especially in the case of temporary pools from rains, which frequently breed very disagreeable local swarms, the use of oil is strongly recommended. The kerosene is applied at the rate of 1 ounce to 15 square feet of water surface, and forms a uniform film over the surface and destroys all forms of aquatic insect life, including the larvæ of the mosquito and also the adult females coming to the water to deposit their eggs. The application retains its efficiency for several weeks, even with the occurrence of heavy rains.

THE RESIN WASH.

This wash has proved of greatest value in California, particularly against red scale (*Aspidiotus aurantii*), and will be of use in all similar climates where the occurrence of comparatively rainless seasons insures the continuance of the wash on the trees for a considerable period, and where, owing to the warmth, the multiplication of the scale insects continues almost without interruption throughout the year. Where rains are liable to occur at short intervals, and in the Northern States, the quicker-acting and stronger kerosene washes are preferable. The resin wash acts by contact, having a certain caustic effect, but principally by forming an impervious, smothering coating over the scale insects. The application may be more liberal than with the kerosene washes, the object being to thoroughly wet the bark.

The wash may be made as follows:

Resin	pounds..	20
Crude caustic soda (78 per cent)	do....	5
Fish oil	pints..	2½
Water to make	gallons..	100

Ordinary commercial resin is used, and the caustic soda is that put up for soap establishments in large 200-pound drums. Smaller quantities may be obtained at soap factories, or the granulated caustic soda (98 per cent) used—3½ pounds of the latter being the equivalent of 5 pounds of the former. Place these substances with the oil in a kettle with water to cover them to a depth of 3 or 4 inches. Boil for one or two hours, making occasional additions of water, or until the compound resembles very strong black coffee. Dilute to one-third the final bulk with hot water, or with cold water added slowly over the fire, making a stock mixture, to be diluted to the full amount as used. When sprayed the mixture should be perfectly fluid, without sediment, and should any appear in the stock mixture reheating should be resorted to.

As a winter wash for scale insects, and particularly for the more resistant San José scale (*Aspidiotus perniciosus*), stronger washes are necessary. In southern California, for this latter insect, the equivalent of a dilution one-third less, or to 66⅔ gallons instead of 100, has given

very good satisfaction. In Maryland, with this insect, it has proved necessary to use the wash at 6 times the summer strength to destroy all of the well-protected hibernating scales; and with other scale insects much stronger mixtures than those used in California have, in the east, proved ineffectual. For regions, therefore, with moderately severe winters, the use of the resin wash to destroy hibernating scale insects seems inadvisable.

TIME TO SPRAY FOR SUCKING INSECTS.

For the larger plant bugs and the aphides, or active plant lice, and all other sucking insects which are present on the plants injuriously for comparatively brief periods, or at most during summer only, the treatment should be immediate, and if in the form of spray on the plants, at a strength which will not injure growing vegetation.

For scale insects and some others, as the pear Psylla, which hibernate on the plants, two or more strengths are advised with most of the liquid insecticides recommended, the weaker for summer applications and the more concentrated as winter washes. The summer washes for scale insects are most effective against the young, and treatment should begin with the first appearance of the larvæ of the spring or any of the later broods, and should be followed at intervals of seven days with two or three additional applications. The first brood, for the majority of species in temperate regions, will appear during the first three weeks in May. Examination from time to time with a hand lens will enable one to determine when the young of any brood appear.

The winter washes may be used whenever summer treatment can not be successfully carried out, and are particularly advantageous in the case of deciduous plants with dense foliage which renders a thorough wetting difficult in summer, or with scale insects which are so irregular in the time of disclosing their young that many summer treatments would be necessary to secure anywhere near complete extermination. In the winter also, with deciduous trees, very much less liquid is required, and the spraying may be much more expeditiously and thoroughly done. In the case of badly infested trees, a vigorous pruning is advisable as a preliminary to treatment.

All of the washes mentioned are excellent as summer remedies. As winter washes for temperate regions the kerosene mixtures and whale-oil soap solutions, particularly the latter, have so far given the best results. These stronger mixtures may be applied at any time during the dormant period of vegetation, and, with deciduous trees, preferably immediately after the falling of the foliage. In the growing season any of these stronger washes would cause the loss of foliage and fruit, and the more concentrated probably the death of the plant.

THE GAS TREATMENT.

Hydrocyanic Acid Gas.

The hydrocyanic acid gas treatment of scale-infested trees, until recently exclusively confined to California, has, within the last year, been introduced in the East by the Department to combat the San José

scale. Briefly, it consists in inclosing a tree (or nursery stock in greater or less quantities at once) with a tent and filling the latter with the poisonous fumes generated with potassium cyanide and sulphuric acid.

The outfit.—The tents are made of blue or brown drilling or 8-ounce duck, and painted or oiled with linseed oil to make them as near air-tight as possible. A very convenient form of tent is made in the shape of a large hexagonal sheet, which, thrown over a tree, will touch the ground on all sides. These sheets or tents are placed over the trees by hand or with poles in case of small trees, but with trees over 10 feet high some sort of a tripod or derrick is used. The outfit for medium-sized trees—tent and derrick—will cost from $15 to $25. A tent for trees 26 feet tall by 60 feet in circumference costs as much as $60.

The chemicals.—Commercial fused potassium cyanide, 58 per cent purity (costing in bulk 40 cents per pound), commercial sulphuric acid (at 3½ cents per pound), and water are used in generating the gas, the proportions being 1 ounce by weight of the cyanide, slightly more than 1 fluid ounce of the acid, and 3 fluid ounces of water to every 150 cubic feet of space inclosed.

The method.—The generator, which may be any glazed earthenware vessel of 1 or 2 gallons' capacity, is placed within the tent under the tree and the water, acid and cyanide, the latter broken up, put in in the order named, after which the operator withdraws from the tent. The tent is allowed to remain on the tree for one-half hour for large trees or fifteen minutes for small ones. The treatment is best made on cloudy days, early in the morning, late in the evening, or at night. Bright, hot sunlight is liable to cause injury to the foliage, which, however, may be largely avoided by using tents of dark material or painted black.

Three or four men can operate six tents at once, and the expense under such conditions, not counting the cost of the outfit, need not be more than 10 cents per tree. One outfit of tents and hoisting apparatus will answer for an entire community or county.

Bisulphide of Carbon Vapor.

In line with the use of hydrocyanic acid gas is the employment of the vapor of bisulphide of carbon to destroy insects on low-growing plants, such as the lice on melon and squash vines. The treatment, as successfully practiced by Professors Garman and Smith, consists in covering the young vines with small tight boxes 12 to 18 inches in diameter, of either wood or paper, and introducing under each box a saucer containing one or two teaspoonfuls (1 or 2 drams) of the very volatile liquid, bisulphide of carbon. The vines of older plants may be wrapped about the hill and gathered in under larger boxes or tubs, and a greater, but proportional, amount of bisulphide used. The covering should be left over the plants for three-quarters of an hour to an hour, and with 50 to 100 boxes a field may be treated with comparative rapidity.

Dusting and Spraying Apparatus.

For the application of powders the dusting bags already described are very satisfactory, or for garden work some of the small powder bellows and blowers are excellent. The best of these cost about $2 each and are on the market in many styles.

Better apparatus is required for the wet applications where successful results require the breaking up of the liquid into a fine mist-like spray. The essential features of such an apparatus are a force pump, several yards of one-half inch cloth-reinforced hose with bamboo hoisting rod, and a spray tip. The size of the apparatus will depend on the amount of vegetation to be treated. For limited garden work and for the treatment of low plants the knapsack pumps or the small bucket force-pumps are suitable, the former costing about $14 and the latter from $6 to $9.

Ready fitted pumps, knapsack and others, for the application of insecticides, are now made by all the leading pump manufacturers of this country and also large reservoirs with pump attached for extended orchard operations, the price of the latter ranging from $25 to $75.

The cost of a spraying outfit for orchard work may be greatly reduced by combining a suitable pump and fixtures with a home-constructed tank or barrel to be mounted on a cart or wagon. A spray-tank having a capacity of about 150 gallons is a very satisfactory size, and may be conveniently made 4 feet long, by 2½ wide by 2 deep, inside measurements. It should be carefully constructed, so as to be water-tight, and should be strengthened by four iron bolts or rods across the ends, one each at the top and bottom. A good double-acting force-pump may be obtained from any of the leading pump manufacturers at a cost of from $10 to $20, depending upon whether of iron or brass, and the nature of its fittings. For use in a very large orchard or in city parks, it may be advisable to construct the tank of twice the capacity mentioned to expedite the spraying and to avoid the more frequent refillings necessary with the smaller tank.

The more economical spray tips in the amount of liquid required are the different styles of cyclone nozzles, the best form of which is known to the market generally as the Vermorel nozzle. These are manufactured by the leading spray pump companies. Other good nozzles are also on the market. The common garden spraying and hose nozzles are much too coarse for satisfactory work, and are wasteful of the liquid.

A prime essential in spraying, especially where the large reservoirs are employed, is to keep the liquid constantly agitated to prevent the settling of the poison to the bottom of the tank. This may be accomplished by constant stirring with a paddle, by shaking, but preferably by throwing a stream of the liquid back into the tank. Many of the larger pumps are now constructed with two discharge orifices with this latter object in view, and the use of such is recommended.

For fruit trees of average size, or, if apple, such as would produce from 10 to 15 bushels of fruit, from 3 to 7 gallons of spray are necessary to thoroughly wet each tree. For smaller trees, such as plum and cherry, 1 gallon to the tree will be sufficient. If an average of 5 gallons to the tree be taken for an apple orchard of 1,000 trees 5,000 gallons of spray would be required. About 33 pounds of paris green or london purple would be needed for one spraying, if used at the rate of 1 pound to 150 gallons of water, and for the two applications ordinarily recommended, 66 pounds. This, for the paris green, at 20 cents a pound, would amount to $13.20, and the london purple, at 10 cents a pound, to $6.60, or a little over 1 cent a tree for the former and one-half a cent for the latter.

In spraying orchard trees, it will be found convenient in going between the rows to spray on either side, half of each tree in the row at a time and finish on the return, rather than attempt to spray all sides of one tree before taking up another.

The object in spraying is to coat every leaf and part of the plant as lightly as feasible with thoroughness, and to avoid waste in doing this a mist spray is essential. The application to any part should stop when water begins to drip from the leaves. A light rain will not remove the poison, but a dashing one will probably necessitate a renewal of the application.

Remedies for Subterranean Insects.

Almost entire dependence is placed on the caustic washes, or those that act externally, for insects living beneath the soil on the roots of plants, including both sucking and biting insects, prominent among which are the white grubs, maggots in roots of cabbage, radishes, onions, etc., cutworms, wireworms, apple and peach root-lice, the grape phylloxera, and many others.

The insecticide must be one that will go into solution and be carried down by water. Of this sort are the kerosene emulsions and resin wash—the former preferable—the potash fertilizers, muriate and kainit, and bisulphide of carbon. Submersion, wherever the practice of irrigation or the natural conditions make it feasible, has also proven of the greatest service against the phylloxera.

Kerosene emulsion and resin wash.—Either the kerosene and soap emulsion or the resin wash, the former diluted 15 times and the latter at the strength of the winter mixture, are used to saturate the soil about the affected plants and either left to be carried down by the action of rains or washed down to greater depths by subsequent waterings.

For the grape phylloxera or the root-louse of the peach or apple, make excavations 2 or 3 feet in diameter and 6 inches deep about the base of the plant, and pour in 5 gallons of the wash. If not a rainy

season, a few hours later wash down with 5 gallons of water and repeat with a like amount the day following. It is better, however, to make this treatment in the spring, when the more frequent rains will take the place of the waterings.

For root maggots enough of the wash is put along at the base of the plant to wet the soil to a depth of 1 to 2 inches, preferably following after an hour with a like amount of water.

For white grubs in strawberry beds or in lawns the surface should be wetted with kerosene emulsion to a depth of 2 or 3 inches, following with copious waterings to be repeated for two or three days. The larvæ go to deeper and deeper levels and eventually die.

Potash fertilizers.—For white grubs, wireworms, cutworms, corn root-worms, and like insects, on the authority of Prof. J. B. Smith, either the kainit or muriate of potash, the former better, are broadcasted in fertilizing quantities, preferable before or during a rain so that the material is dissolved and carried into the soil at once. These not only act to destroy the larvæ in the soil, but are deterrents, and truck lands constantly fertilized by these substances are noticeably free from attacks of insects. This, in a measure, results from the increased vigor and greater resistant power of the plant, which, of itself, more than compensates for the cost of the treatment. The value of these fertilizers against the wireworms is, however, questioned by Prof. J. H. Comstock.

For the root-louse of peach and apple work the fertilizer into the general surface of the soil about the trees, or put it in a trench about the tree 2 feet distant from the trunk.

For cabbage and onion maggots apply in little trenches along the roots at the rate of 300 to 500 pounds to the acre, and cover with soil.

These fertilizers (and the nitrate of soda is nearly as good) are also destructive to the various insects which enter the soil for hibernation or to undergo transformation.

Bisulphide of carbon.—This is the great French remedy for the phylloxera, 150,000 acres being now subjected to treatment with it, and applies equally well to all other root-inhabiting lice. The treatment is made at any season except the period of ripening of the fruit, and consists in making holes about the vines 1 foot to 16 inches deep and pouring into each about one-half ounce of bisulphide, and closing the hole with the foot. These injections are made about 1½ feet apart, and not closer to the vines than 1 foot. It is better to make a large number of small doses than a few large ones. Hand injectors and injecting plows are employed in France to put the bisulphide into the soil about the vines, but a short stick or iron bar may be made to take the place of these injectors for limited tracts.

For root maggots a teaspoonful is poured into a hole at the base of the plant, covering as above.

For ant nests an ounce of the substance is poured into each of sev-

eral holes made in the space occupied by the ants, the openings being then closed, or the action is made more rapid by covering with a wet blanket for ten minutes and then exploding the vapor at the mouth of the holes with a torch, the explosion driving the fumes more thoroughly through the soil.

Submersion.—This very successful means against the phylloxera is now practiced over some 75,000 acres of vineyards in France which were once destroyed by the grape root-louse, and the production and quality of fruit has been fully restored. In this country it will be particularly available in California and in all arid districts where irrigation is practiced, otherwise it will be too expensive to be profitable. The best results are secured in soils in which the water will penetrate rather slowly, or from 6 to 18 inches in twenty-four hours; in loose, sandy soils it is impracticable on account of the great amount of water required. Submersion consists in keeping the soil of the vineyard flooded for from eight to twenty days after the fruit has been gathered and active growth of the vine ceased, or during September or October, but while the phylloxera is still in active development. Early in September eight to ten days will suffice; in October, fifteen to twenty days, and during the winter, as was formerly practiced, forty to sixty days. Supplementing the short fall submergence a liberal July irrigation, amounting to a forty-eight-hour flooding, is customary to reach any individuals surviving the fall treatment, and which in midsummer are very susceptible to the action of water.

To facilitate the operation vineyards are commonly divided by embankments of earth into square or rectangular plots, the former for level and the latter for sloping ground, the retaining walls being protected by coverings of reed grass, etc., during the first year, or until they may be seeded to some forage plant.

This treatment will destroy many other root-attacking insects or those hibernating beneath the soil, and, in fact, is a very ancient practice in certain oriental countries bordering the Black Sea and the Grecian Archipelago.

Remedies for Insects Affecting Grain and other Stored Products.

The chief loss in this direction from insects is to grains in farmers' bins, or grain or grain products in stores, mills, and elevators, although in the warmer latitudes much of the injury results from infestation in the field between the ripening of the grain and its storage in bins or granaries. Fortunately, the several important grain insects are amenable to like treatment. Aside from various important preventive considerations, such as, in the South, prompt threshing of grain after harvesting, the thorough cleansing of bins before refilling, constant sweeping, removal of waste harboring insects from all parts of granaries and mills, and care to prevent the introduction of "weeviled" grain,

there are three valuable remedial measures, viz, agitation of the grain, heating, and dosing with bisulphide of carbon.

The value of agitating or handling grain is well known, and whenever, as in elevators, grain can be transferred or poured from one bin into another grain pests are not likely to trouble. The benefit will depend upon the frequency and thoroughness of the agitation, and in France machines for shaking the grain violently have been used with success. Winnowing weeviled grain is also an excellent preliminary treatment.

Raising the temperature of the grain in closed retorts or revolving cylinders to 130° to 150° F. will kill the inclosed insects if continued for from three to five hours, but is apt to injure the germ, and is not advised in case of seed stock. The simplest, cheapest, and most effectual remedy is the use of bisulphide of carbon.

BISULPHIDE OF CARBON.

This is a colorless liquid with very offensive odor, which, however, passes off completely in a short time. It readily volatilizes and the vapor, which is very deadly to insect life, is heavier than air and settles and fills any compartment or bin in the top of which the liquid is placed. It may be distributed in shallow dishes or tins or in saturated waste on the top of grain in bins, and the gas will settle and permeate throughout the mass of the grain. In large bins, to hasten and equalize the operation, it is well to put a quantity of the bisulphide in the center of the grain by thrusting in balls of cotton or waste tied to a stick and saturated with the liquid, or by means of a gas pipe loosely plugged at one end, down which the liquid may be poured and the plug then loosened with a rod. In moderately tight bins no further precaution than to close them well need be taken, but in open bins it will be necessary to cover them over with a blanket to prevent the too rapid dissipation of the vapor. The bins or buildings should be kept closed from 24 to 36 hours, after which a thorough airing should be given them.

Limited quantities at a time may often be advantageously subjected to treatment in small bins before being placed for long storage in large masses, and especially whenever there is danger of introducing infested grain.

The bisulphide is applied at the rate of 1 pound to the ton of grain, or a pound to a cubic space 10 feet on a side.

In the case of mills, elevators, or larger granaries the application may be best made on Saturday night, leaving the building closed over Sunday, with a watchman without to see that no one enters and to guard against fire. The bisulphide should be first distributed in the lower story, working upward to avoid the settling vapor, using the substance very freely, in waste or dishes, at all points of infestation and over bins throughout the building.

This insecticide may also be used in other stored products, as pease, beans, etc., and very satisfactorily where the infested material can be inclosed in a tight can, chest or closet for treatment.

The bisulphide costs, in 50-pound cans, 10 cents per pound, and in small quantities, of druggists, 25 to 35 cents per pound.

Caution.—The bisulphide may be more freely employed with milling grain than that intended for seeding, since used excessively it is liable to injure the germ. It must always be remembered that the vapor is highly inflammable and explosive, and that no fire or lighted cigars, etc., should be in the building during its use. If obtained in large quantities it should be kept in tightly closed vessels and away from fire, preferably in a small outbuilding.

Control of Insects by Cultural Methods.

It is much easier to ward off an attack of insects or to make conditions unfavorable for their multiplication than to destroy them after they are once in possession; and in controlling them, methods and systems of farm and orchard culture have long been recognized as of the greatest value—more so even than the employment of insecticides, which, in most cases, can only stop an injury already begun. Insects thrive on neglect, multiply best in land seldom or never cultivated, and winter over in rubbish, prunings, or the undisturbed soil about their food plants, and become, under these conditions, more numerous every year. It is a fact of common observation that it is the neglected farm, vineyard, or orchard filled with weeds or wild growth which is certain to be stocked with all the principal insect enemies; and, on the other hand, thorough and constant culture, with the removal and burning of prunings, stubble, and other waste, the collection and destruction of fallen and diseased fruit, and the practice, where possible, of fall plowing to disturb the hibernating quarters of field insects, will almost certainly be accompanied by comparative immunity from insect pests.

The vigor and healthfulness of plant growth has also much to do with freedom from insect injury, such plants seeming to have a native power of resistance which renders them, in a measure, distasteful to most insects, or at least able to throw off or withstand their attacks. A plant already weakened, however, or of lessened vitality from any cause, seems to be especially sought after, is almost sure to be the first affected,and furnishes a starting point for general infestation. Anything, therefore, which aids good culture in keeping plants strong and vigorous, such as the judicious use of fertilizers, will materially assist in preventing injury.

To the constant cropping of large areas of land year after year to the same staple is largely due the excessive loss from insects in this country as compared with European countries, because this practice furnishes the best possible conditions for the multiplication of the

enemies of such crops. A most valuable cultural means, therefore, is a system of rotation of crops which will prevent the gradual yearly increase of the enemies of any particular staple by the substitution every year or two of other cultures not subject to the attacks of the insect enemies of the first.

With such insects as the Hessian fly, the squash borers, and many others which have regular times of appearance, much can be done, also, by the planting of early or late varieties, or by deferring seeding so as to avoid the periods of excessive danger. Wherever possible, varieties should be selected which experience has shown to be resistant to insect attack. Familiar illustrations of such resistant varieties in all classes of cultivated plants will occur to every practical man, and a better instance of the benefit to be derived from taking advantage of this knowledge can not be given than the almost universal adoption of resistant American vines as stocks for the regeneration of the vineyards of France destroyed by the phylloxera.

In the case of stored grain pests, particularly the Angoumois moth, or so-called fly weevil, the chief danger in the South is while the grain is standing in shock or stack, after harvesting, during which period the insects have easy access to it. This source of infestation may be avoided by promptly threshing grain after harvesting and storing it in bulk. This will prevent the injury of more than the surface layer, as the insects are not likely to penetrate deeply into the mass of the grain.

These general notes are by no means new, but their importance justifies their repetition, as indicating the best preventive measures in connection with the remedial ones already given.

The Profit in Remedial Measures.

The overwhelming experience of the past dozen years makes it almost unnecessary to urge, on the ground of pecuniary returns, the adoption of the measures recommended in the foregoing pages against insects. To emphasize the value of such practice, it is only necessary to call attention to the fact that the loss to orchard, garden, and farm crops frequently amounts to from 15 to 75 per cent of the entire product, and innumerable instances could be pointed out where such loss has been sustained year after year, while now, by the adoption of remedial measures, large yields are regularly secured with an insignificant expenditure for treatment. It has been established that in the case of the apple crop, spraying will protect from 50 to 75 per cent of the fruit which would otherwise be wormy, and that in actual marketing experience the price has been enhanced from $1 to $2.50 per barrel, and this at a cost of only about 10 cents per tree for labor and material.

In the case of one orchard in Virginia, only one-third of which was sprayed, the result was an increase in the yield of sound fruit in the portion treated of nearly 50 per cent, and an increase of the value of this fruit over the rest of 100 per cent. The loss from not having treated

the other two-thirds was estimated at $2,500. The saving to the plum crop and other small fruits frequently amounts to the securing of a perfect crop where otherwise no yield whatever of sound fruit could be secured.

An illustration, in the case of field insects, may also be given where, by the adoption of a system of rotation, in which oats were made to alternate with corn, the owner of a large farm in Indiana made a saving of $10,000 per year, this amount representing the loss previously sustained annually from the corn root-worm. The cotton crop, which formerly in years of bad infestation by the leaf-worm was estimated to be injured to the extent of $30,000,000, is now comparatively free from such injury, owing to the general use of arsenicals.

Facts of like import could be adduced in regard to many other leading staples, but the foregoing are sufficient to emphasize the money value of intelligent action against insect enemies, which, with the present competition and diminishing prices, may represent the difference between a profit or a loss in agricultural operations.